Convection in Extratropical Cyclones: Analysis of GPM and NEXRAD

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INTRODUCTION: Extratropical cyclones (ETCs) are the most common cause of extreme precipitation in the mid-latitudes. Vertical motion within an ETC can be driven by isentropic lifting, upright convection and slantwise convection. These different mechanisms can deliver different rain rates and might respond differently to global warming. Also, the profile of condensational heating associated with these different pathways impact the storms differently.

GOALS:
⇒ Compare different metrics for identifying convection within the ETCs and calculate the relative contribution of convection to total ETC precipitation.
⇒ Determine if convection occurs preferentially in specific regions of the storm and decide how to best utilize GPM retrievals covering other parts of the mid-latitudes.

CASE-STUDY EXAMPLES

Sept 21, 2015 @ 11Z
Virginia and North Carolina: poleward of a warm front in a developing ETC. GPM convection is nearly equal, in terms of core sizes and locations, to that of the NEXRAD vertical-scan method. Modified Steiner method overestimates convection. Precip vs. Stage IV shows large difference.
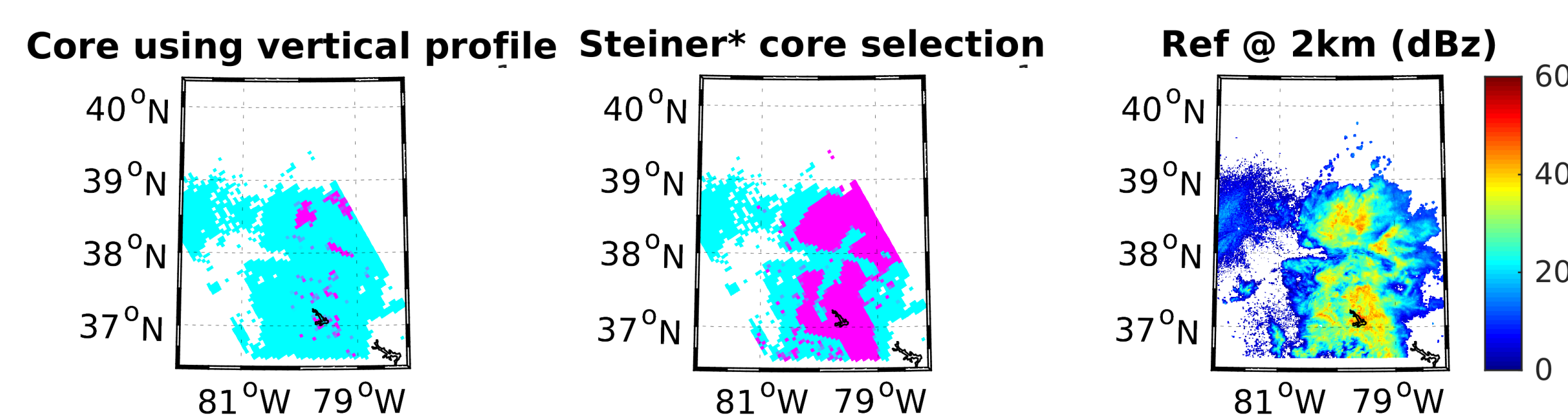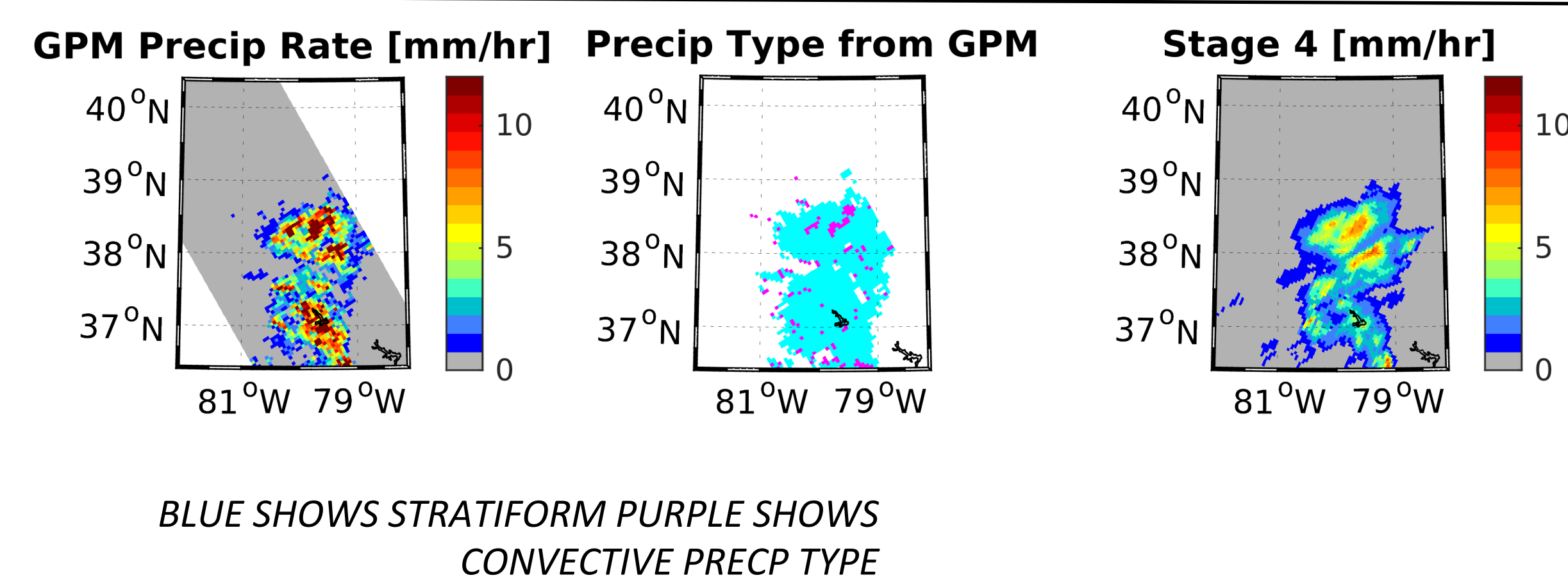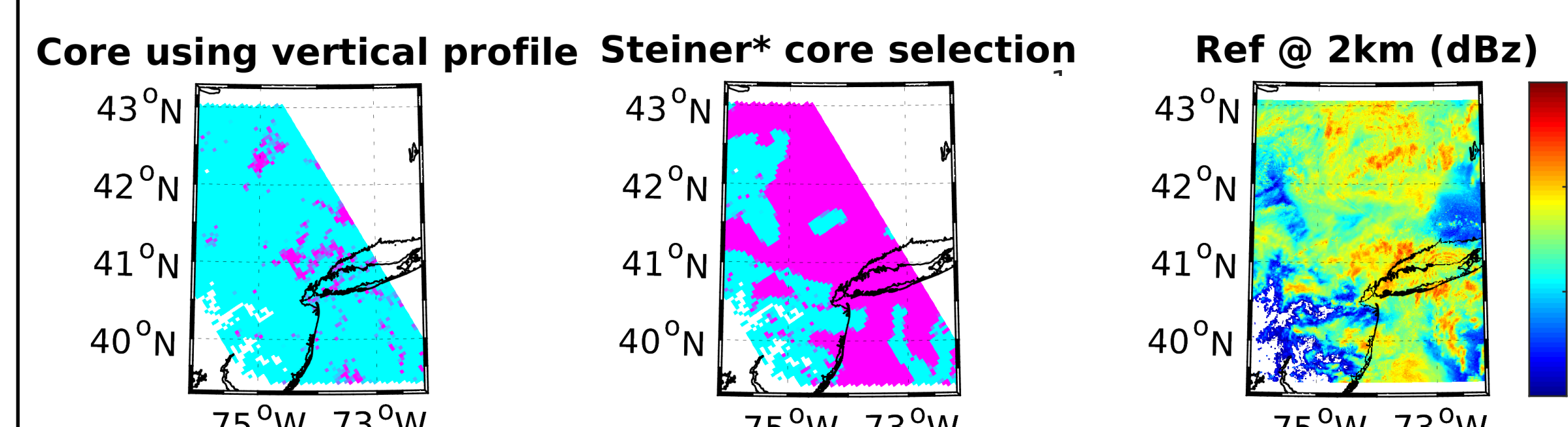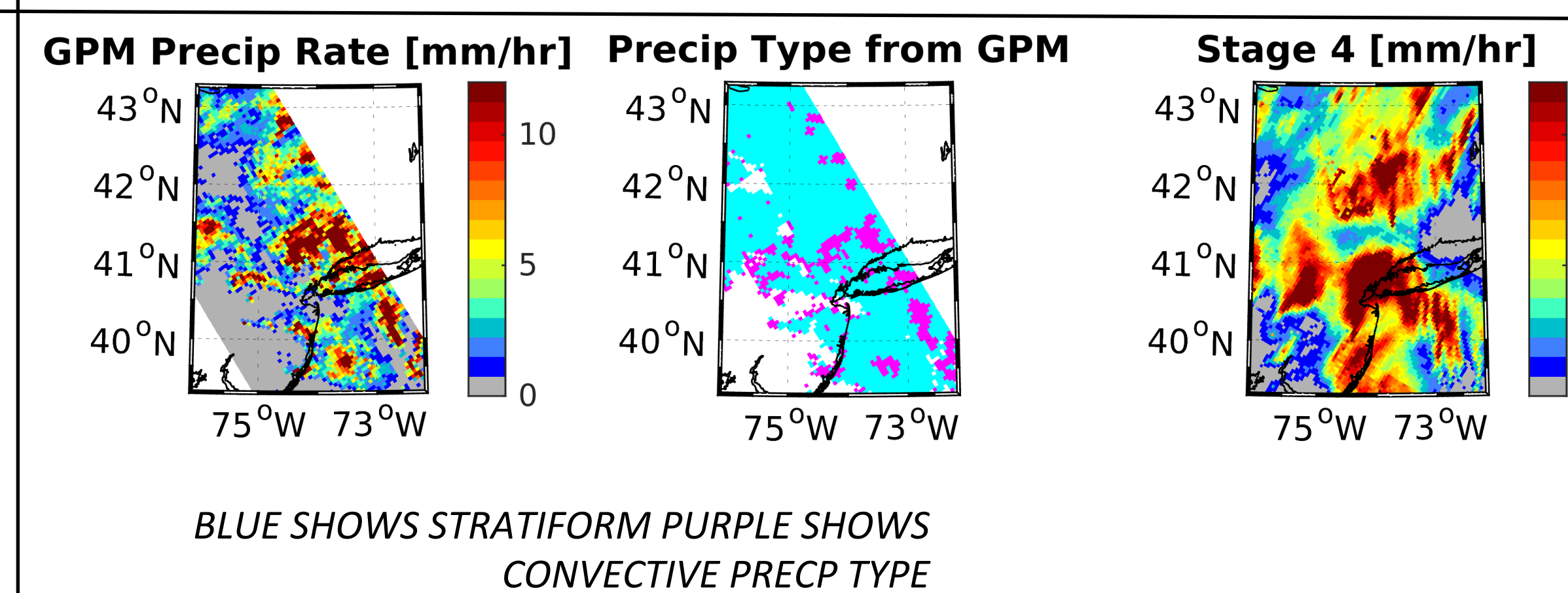
July 9, 2015 @ 23Z:
East Pennsylvania: within warm sector of developing ETC. GPM shows slightly less convection that NEXRAD vert-scan. Timing differs, with GPM occurring earlier, may relate to difference.
Precip. shows strong rates in both GPM and Stage 4.
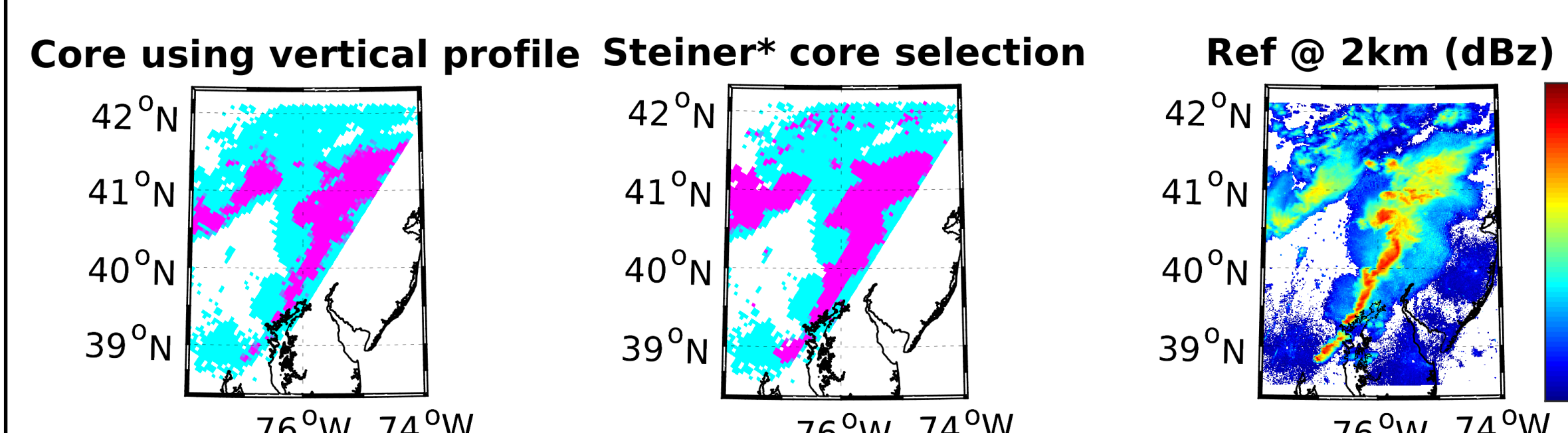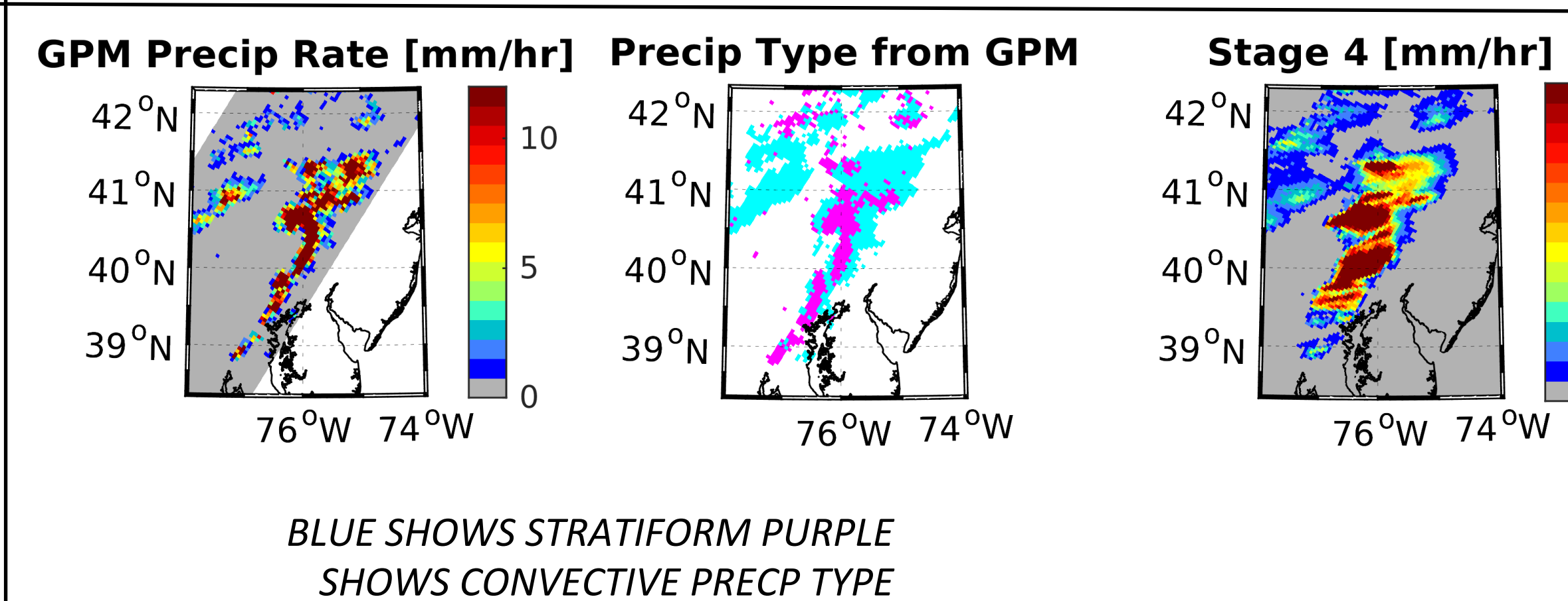
Sept. 30, 2015 @ 7Z:
NY and Connecticut: at location of developing ETC along an existing cold front.
GPM identifies more convection than NEXRAD vert-scan. The timing, as seen in the NEXRAD 2km reflectivity panel is very similar in this case.

BLUE SHOWS STRATIFORM PURPLE SHOWS CONVECTIVE PRECP TYPE

METHODOLOGY

- In the GPM **L2 CMB DPR+GMI** files, identify strong rain events. To this, we find passes that are over the US and then retain events with precipitation above a threshold (*see schematic*)

  (*Note that for 2015, we found 430 potential cases over the whole US. This poster will focus on the **Eastern US**, giving us 112 cases.*)

- For the dates of these events, grab the 3-dimensional NEXRAD Level II data for all radars within 400 km of the precipitation region. Analyzed using Py-ART.
- Also grab NEXRAD precipitation data (Stage IV).
- Compare convective core regions identified in satellite data, via GPM algorithm, with those identified in NEXRAD data.
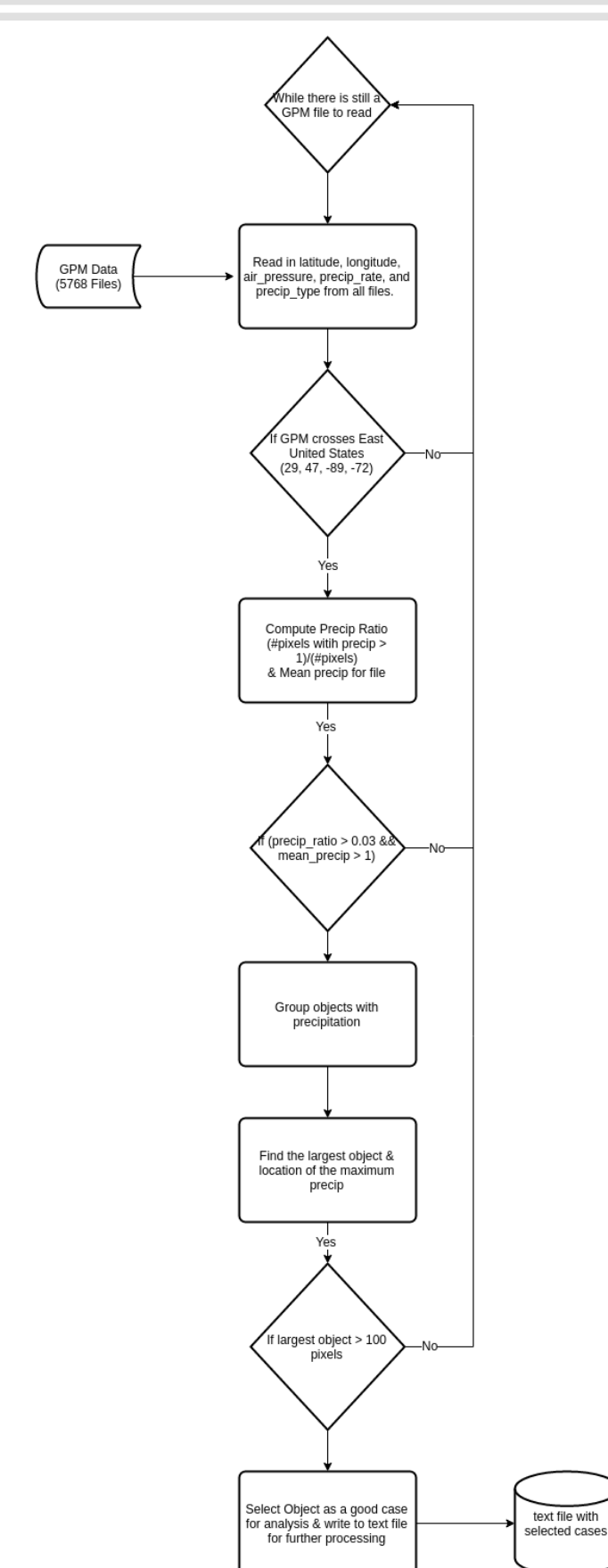
ANALYSIS OF PRECIPITATION TYPE VS. ALGORITHM

We re-grid the core selection of the NEXRAD data, into the GPM grid and swath path. From the re-gridded cores, we find the number of pixels for which convective core is selected as well as the number of total pixels that have precipitation. Then we analyze the sizes of the contiguous convective cores and we obtain a ratio/percentage of convective cores to stratiform.

PIXEL SIZES FOR THE CONVECTIVE CORES

Excluding cases with < 3 pixels.
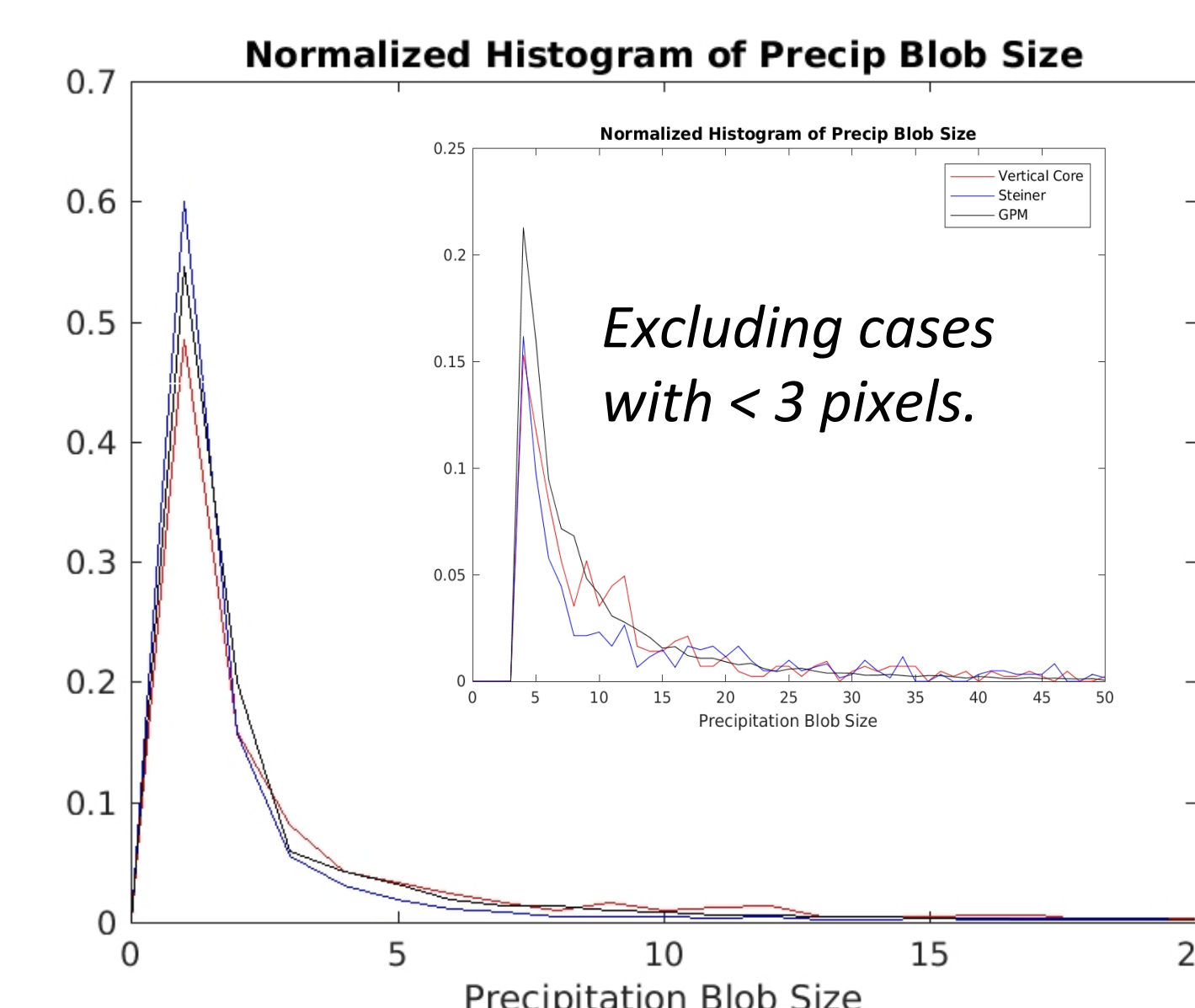
Figure 2: Contiguous convective core regions (i.e., blobs) sizes for different core selection criteria. We group the precipitation objects and count number of pixels for each object. *The x-axis is cut-off at 20 pixels, though there are cases with larger sizes.*

RATIO OF CONVECTIVE TO STRATIFORM PRECIP
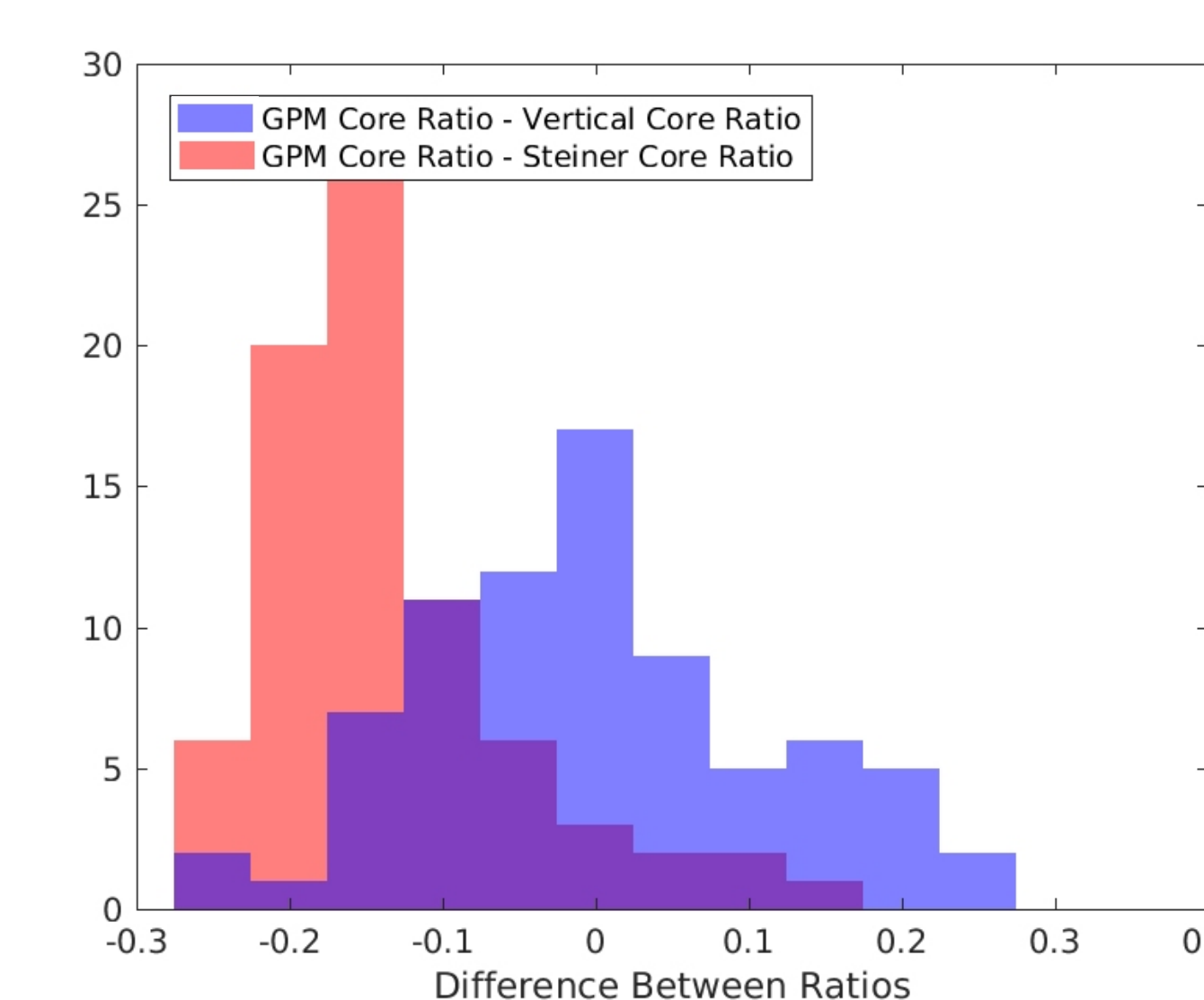
Figure 3: Histogram of difference between GPM Core ratio and Vertical Core Ratio (red) and GPM Core Ratio and Steiner Core Ratio (blue)

CONVECTIVE CORE ALGORITHMS

GPM (*two methods used, then unified*)
Vertical profiling method: detect bright band (BB) by examining vertical profile of the radar reflectivity factor (Z). When BB is detected, rain type is stratiform if reflectivity in the rain region does not exceed a threshold. When BB is not detected and reflectivity factor exceeds a threshold, rain type is convective.

Horizontal pattern method: Rain type is classified using a modified Steiner et al (1995) method.
Meneghini and Iguchi et al. GPM/DPR Level 2 Algorithm Theoretical Basis Document (2010).

Jeyaratnam/Luo/Booth Algorithm
If a column of data has a 40 dBz radar reading above 6km, it is selected as a convective core.

Simplified Steiner et al. (1995) Algorithm
Identify pixels exceeding 40 dBz at 2km. A mean background reflectivity (bg_ref) is computed for each pixel (mean of reflectivity around a 20 pixel rectangular box was used to compute this value). ΔZ = pixel reflectivity value - background reflectivity value. If the bg_ref < 0 and ΔZ > 10, it is selected as a core. Similarly the conditions are chosen for different bg_ref values as shown below.

$$\Delta Z = \begin{cases} 10, \rightarrow Z_{bg} < 0 \\ 10 - Z_{bg}^2/180, \rightarrow 0 \leq Z_{bg} < 42.43 \\ 0, \rightarrow Z_{bg} \geq 42.43 \end{cases}$$

For the selected convective core pixels, surrounding pixels also may be selected, depending on the background reflectivity. We use 1 pixel in lieu of 1 km for the radius.
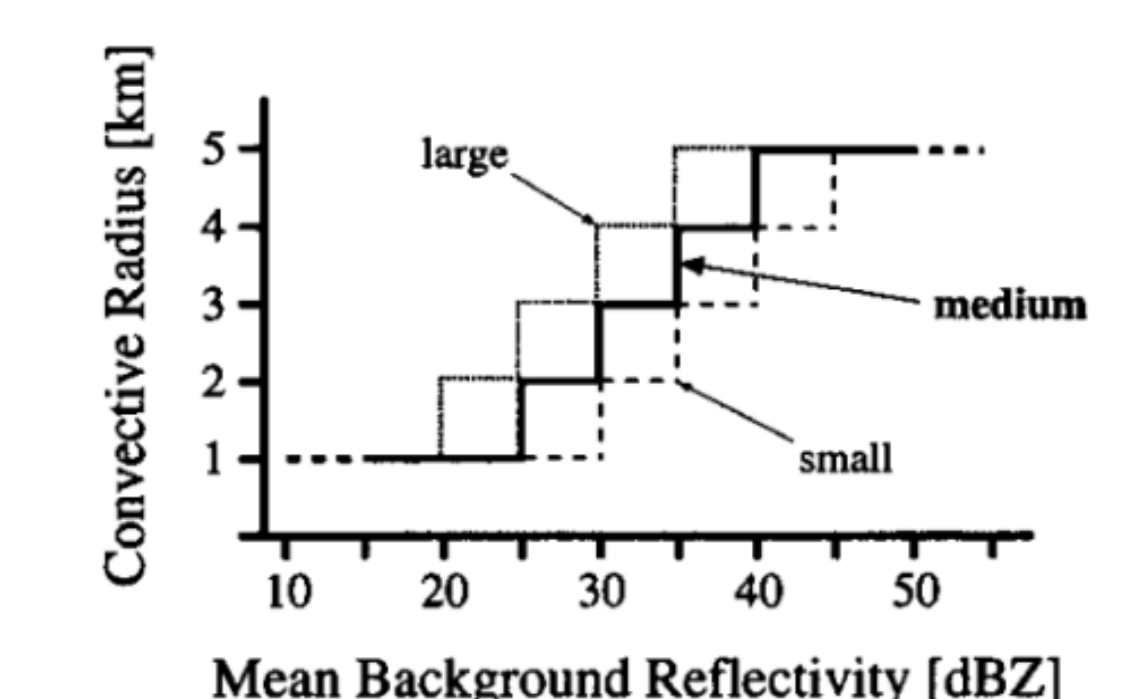

Fig 6b from: Steiner, Matthias, Robert A. Houze Jr., and Sandra E. Yuter. 1995. "Climatological Characterization of Three-Dimensional Storm Structure from Operational Radar and Rain Gauge Data." *Journal of Applied Meteorology* 34 (9): 1978–2007.